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Wright-Patterson Air Force Base, Ohio

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AN ANALYSIS OF FIRE INCIDENTS IN MILITARY AIRCRAFT HANGARS: THE COMPUTERIZED DATA BASE AN EFFECTIVE TOOL

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This thesis analyzes an existing United States Navy computerized data base of fire incidents in aircraft hangars to demonstrate the usefulness of such a data base as a management tool and also the need for a similar data base in the United States Air Force. The analysis is accomplished using the Statistical Package for Social Sciences (SPSS) program to perform frequency, crosstabulation and breakdown operations on the data base. The authors concluded that the effective assessment of fire loss potential and the justification of existing or proposed fire protection policy could be greatly enhanced by information on the frequency, causes, and behavior of historical fire incidents.

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AN ANALYSIS OF FIRE INCIDENTS IN MILITARY AIRCRAFT HANGARS: THE COMPUTERIZED DATA BASE AN EFFECTIVE TOOL

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Facilities Management

By

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CHAPTER I

INTRODUCTION

Background

Effective fire protection for aircraft hangars has been the concern of fire protection engineers for many years (11). Both the hangar structure and the aircraft within represent considerable monetary investments. The advent of complex, technologically advanced military aircraft introduced a new dimension: The cost of the newer aircraft became two or three fold higher than aircraft manufactured prior to 1968 (6:1). A new policy of fire protection for aircraft hangars emerged in the United States Air Force (USAF) placing greater emphasis on protecting the hangared aircraft than the hangar structure (15). In developing a standard for the fire protection of hangars, it would be simple to recommend the use of all known detection and protection systems, but with the size of hangars and the high capital and maintenance costs of these systems such a proposal would be quite unrealistic.

Problem Statement

A computerized data base of fire incidents in aircraft hangars could be an effective tool for assessing fire loss potential and also for justifying existing or

proposed fire protection policy for hangars (8). To date, such a data base has not been compiled in the USAF (8).

Justification

"Since the technological development of aircraft has been and continues to be a dynamic process . . . [7:5]," it has been almost impossible to answer all the questions concerning adequate fire protection which exist at any given time. The Director, Fire Protection Division (USAF), has advised that an effective assessment of fire loss potential and justification of existing or proposed fire protection policy would be greatly enhanced by information on frequency, causes, and behavior of previous fire incidents in aircraft hangars. He expressed the need for the compilation of a data base of fire incidents (8). A study conducted in 1973 also recommended the need for a data base of fire incidents (3:147). Such a data base should be used to address the problem of deficiencies in existing fire detection and protection systems in aircraft hangars.

The Air Force Logistics Command (AFLC) in late 1977 contracted for an investigation of effective levels of fire detection and protection in aircraft hangars (15). This contract did not address the need for the compilation and utilization of computerized data base of fire incidents in military aircraft hangars. This contract was considered

necessary despite previous similar USAF-sponsored contracts (3; 6; 7). Uncertainty of what is an acceptable level of fire protection in aircraft hangars still exists. The Chief, Fire Protection Engineer (AFLC) believes that the current policy could be inadequate (15).

Research Objectives

There are three objectives associated with this study:

1. Utilizing an existing United States Navy (USN) computerized data base of fire incidents in USN aircraft hangars, determine if significant relationships exist between variables identified in the data base.

2. Identify how a computerized data base can be utilized in assessing fire loss potential and in justifying existing or proposed fire protection policy for military hangars.

3. Identify what variables should be included in a computerized data base to better accomplish objective number 2.

Literature Review

USAF Study

In 1973, a study on fire protection for large Air Force hangars recommended the compilation of a statistical data base of fire incidents in hangars (3:147). The objective of this study was to prepare new design

paramaters for fire protection purposes in large Air Force hangars emphasizing the protection of the aircraft from major damage from large fires as a result of fuel spills. The study analyzed the nature of fire hazards present in hangars in terms of the fuel and ignition sources, and examined the personnel injury, aircraft damage, and hangar damage that could result from a fire incident. Fire detection systems and suppression systems were also examined. Rolf Jensen and Associates, Incorporated (2:148), who conducted the study stated:

> . . . it is recommended that a program for collection and analyzing hangar fire data and related incident reports be established . . . so that future risk analysis can be made on a better statistical base.

Interviews with Mr. Victor Robinson, Headquarters USAF/PREMF, and also Mr. Morgan, Director, Fire Protection, USAF, have revealed that no study has been conducted on statistical evaluation of fire incidents in aircraft hangars in the USAF. Mr. Morgan strongly supported the need for such a data base (8).

USAF Policy

An understanding of USAF policy and regulations for fire protection in aircraft hangars was obtained from USAF fire protection publications. The following paragraphs review the policy/regulations which are directly related to this thesis study.

Materials. Hangars and their contiguous shops will be of unprotected noncombustible construction (12:p.2-2).

Fire Walls. Fire walls are used to prevent the horizontal spread of fire. AFR 92-1 (13:p.2-2) states that fire walls ". . . must be designed to resist the most severe fire expected for its anticipated duration." Also all openings in these walls will be protected by fire doors and there will be curbs, ramps or stairs at all floor levels opening from the aircraft areas to prevent the flow of liquids through the openings (12:p.13-5).

Draft Stops.[1] Draft stops are installed to confine the spread of hot gases from a fire and limit the number of overhead sprinkler heads that will automatically open to those sprinkler heads that will most effectively suppress the fire (12:A-70).

Drainage System. Hangar floor drains are necessary to restrict the spread of spilled fuel and reduce its fire and explosion hazard (12:A-71). AFM 88-15 (12:A-71) states that "hangar floor drains will be trenches covered with a steel grating located adjacent to and inside door rail mountings." This publication also requires that in

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[1]Draft stops, or curtains, usually surround each sprinkler zone and extend down from the ceiling not less than one-third of the distance from the ceiling to the floor (12:A-70).

pull-through hangars ". . . the floor will be sloped 1/16 inch per foot towards the door locations [12:A-71]."

Proximity of the Fire Station. The response time and distance of the base fire department to a hangar are not greater than 4-1/2 minutes and one to two miles respectively (13:p.1-1).

Automatic Fire Suppression Systems. AFM 88-15 states that closed head preaction foam-water over head sprinkler systems and supplementary foam-water systems will be provided in aircraft hangars. Existing water deluge systems in hangars are considered adequate if the hangars meet the floor space requirements of NFPA-40-1969 (12:p.13-5).

Sprinkler systems are not necessarily required in hangars where aircraft fuel tanks are emptied and purged prior to entry into the hangar. This determination will be made by the major command (12:p.13-5).

The shape and location of various aircraft in a hangar may render the overhead sprinkler system ineffective. For this reason, ". . . a supplementary system of waterpowered oscillating monitor nozzles will be provided to protect the underwing and fuel-loaded portions of hangared aircraft [12:A-70]."

Fire Detection Systems. In hangars protected by foam-water sprinkler systems, ". . . fire detection and activation of any monitor nozzles must be through the use of lightning and welding blind ultra-violet detectors [12:A-70]." The system will be designed such that ". . . the activation of any two detectors will actuate the under aircraft protection system [12:A-70]." Activation of one detector will sound a local alarm and alert the fire department (12:A-70).

"Rate of temperature rise detectors will be used to actuate an alarm and the overhead sprinkler system [9:409-19]."

Security of Fire Protection Systems. In hangar areas the complete status of sprinkler systems must be supervised (status monitored electrically). This supervision includes water pressure, electrical power, sprinkler valves, system activation, and manual activation (12:A-70). Furthermore, waterflow alarms giving both local and fire department signals will be installed on all automatic sprinkler systems (12:p.13-17).

USN Policy

The Assistant for Fire Protection Engineering, USN, Washington, was consulted concerning the USN policy for fire protection in aircraft hangars (1). From this consultation, it was determined that the USN policy

compares closely with the USAF policy discussed above with the following exceptions:

1. Ultra-violet detection systems are not used in USN hangars because the Navy considers that these detectors contribute to a high incidence of false alarms.

2. Oscillating water-foam monitors are activated by push button or when the overhead sprinkler system actuates. The USAF policy calls for a separate automatic detection system for the activation of the oscillating monitors.

3. Control valves for sprinkler systems are locked open, but not electrically supervised.

USAF Assumptions

The assumptions on which USAF policy for fire protection in aircraft hangars is based was obtained from the Chief of Fire Protection, AFLC (15). These assumptions are detailed in Appendix A.

Roof Venting

In Australia in 1972, a series of tests were conducted in an unused aircraft hangar to obtain data for the design of automatic roof venting systems for single-story buildings of large floor area such as aircraft hangars. Trays of aviation kerosene were burned and the interaction of four variables were investigated.

These variables were fire area, roof-vent area, wall-inlet area, and depth of roof curtain (draft stop) (5:1). The total of 111 experiments of severe fires in the timber-framed structure demonstrated that provided a fire is of short duration, as should be the case with prompt and efficient fire fighting, the discharge of hot gases through the roof will localize the fire damage (5:120).

The Department of Construction, the Commonwealth of Australia construction authority, specifies roof venting for fire in single-story buildings including aircraft hangars (2:3). This department advocates that fire venting is required for the following reasons (2:4).

a. To reduce damage to the building contents by:

1. facilitating the escape from building of hot gases rising from the fire, thus reducing build-up of heat which would probably accelerate fire growth in the contents;

2. venting unburned combustion gases, thus reducing the risk of explosion that can spread fire and cause other damage;

3. containing hot gases from a fire within a limited compartmented area under the roof; and

4. promoting more complete combustion, thus reducing smoke production; smoke damage, and obscuration of the fire situation.

b. To reduce damage to the structure by:

1. restricting the spread of hot gases under the roof;

2. reducing the risk of explosion damage to the structure; and

3. reducing the spread of corrosive decomposition products and smoke damage.

c. To assist fire fighting operations by:

1. permitting the discharge of smoke and hot gases, thus reducing the depth of the layer of hot gases under the roof and keeping the atmosphere near the floor cool and clear; and

2. minimizing the accumulation of toxic decomposition products and the production of carbon monoxide.

Research Questions

In order to accomplish the research objectives, three research questions will be addressed:

1. Do significant relationships exist between the variables identified in the USN computerized data base?

2. If significant relationships do exist between the variables, can the results be utilized to assess fire loss potential and also to justify fire protection policy in military hangars?

3. What variables are considered necessary for inclusion in a computerized data base of fire incidents in aircraft hangars?

CHAPTER II

METHODOLOGY

Data Collection

Information on fires involving USAF aircraft hangars was obtained from USAF Inspection and Safety Center, Norton Air Force Base. However, as this information did not differentiate between fires inside hangars from fires involving aircraft outside hangars, the information was not useful for compiling an USAF computerized data base for fire incidents inside hangars.

A computerized data base of all fire incidents in USN hangars during the period 1 January 1968 to 31 December 1977 was obtained from the Naval Safety Center, Naval Air Station, Norfolk, Virginia.

Variables

The following list of variables is included in the data base (14):

Number of Fire Alarms in USN Aircraft Hangars. This is a census of all reported fire alarms in USN aircraft hangars during the period 1 January 1968 to 31 December 1977.

__Time and Date of Alarm__. This variable identifies the time of day, to the nearest minute on a twenty-four hour clock, that the alarm was received at the fire station. It also identifies the day, month and year of the alarm.

__Type of Alarm__. This variable identifies whether the fire alarm was due to the automatic or manual operation of a fixed extinguishing system. This variable also identifies false alarms (alarms when no fire occurred).

__Hangar Occupancy__. This variable identifies whether the hangar was a Navy-operated hangar, a hangar under construction, or a Navy-owned hangar used for private operations.

__Major Factors Contributing to Spread of Fire__. This variable identifies what primary factor caused the fire to spread from its initial ignition source.

__Sprinkler Status__. This variable identifies the type of sprinkler system installed, if any; why the system operated if there was no fire; and what effect it had on the fire if the system operated in response to a fire.

__Number of Sprinkler Heads that Operated__. This variable identifies the number of sprinkler heads, if any, that automatically operated.

Sprinkler Coverage. This variable identifies the percentage of the hangar that was covered by the operating sprinkler heads.

Automatic Fire Alarm Systems. This variable identifies the type of automatic fire alarm system installed in the hangar, if any; and, if installed, whether it operated satisfactorily or not.

Manual Fire Alarm Systems. This variable identifies whether a manual alarm system was installed in the hangar; if installed whether it was connected to the fire station; and whether it operated satisfactorily or not.

Portable Fire Extinguishers. This variable identifies whether portable fire extinguishers were available in the hangar; and if available were they used satisfactorily prior to the arrival of the fire department.

Method of Detection. This variable identifies the method of detection of the fire by individuals, or by automatic system.

Method of Alarm Transmittal. This variable identifies how the fire service received the fire alarm.

Cause of Fire. This variable identifies the source of ignition and initial source of fuel for the fire.

Outside Aid. This variable identifies whether non-Navy fire fighting services were requested and used.

Method of Control. This variable identifies what equipment extinguished the fire.

Government Dollar Loss. This variable identifies to the nearest dollar the value of fire loss to government building and/or the government owned contents of the buildings.

Number of Fire Related Injuries. This variable identifies the number of individuals injured as a result of the fire.

Number of Fire Related Deaths. This variable identifies the number of individuals that died as a result of the fire.

Type of Construction and Interior Finish. This variable identifies the type of materiel used in constructing and finishing the interior of the hangar.

Major Cause of Fire. This variable identifies the major cause of the fire.

A listing of nominal responses possible in the USN computerized data base is included in Appendix B.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) system of computer programs was used to compute frequency, crosstabulation, and breakdown tables on the USN aircraft hangar fire data (10).

One-way frequency distribution tables were generated to determine which variables in the data base had sufficient variability to be useful in subsequent analysis. The relationships between two or more variables were examined using crosstabulation and breakdown analysis procedures. The computer output was then examined for significant relationships between two or more variables.

Crosstabulation is " . . . a joint frequency distribution of cases according to two or more classificatory variables [10:218]." Breakdown procedures calculate and print . . . "the sums, means, standard deviations, and variances of a dependent variable among subgroups of the cases in the file [10:249]." Total dollar loss was used as the dependent variable in the breakdown analysis.

The cost information in the data base and in this study reflects the loss in dollar value at the time of the incident and is not in 1978 dollars. For the purposes of clarity, all tables in this study are presented in crosstabulation format.

CHAPTER III

ANALYSIS OF FIRE INCIDENT DATA

General

The computerized data base for all fire incidents in USN aircraft hangars during the period 1 January 1968 to 31 December 1977 contains 544 cases of reported fire alarms. These cases can be categorized into the following: 358 involving false alarms[1] and 186 involving actual fire incidents.

Table 1[2] details the reported causes of the 186 fire incidents by frequency and total dollar loss for fires with individual losses less than $10,000 and greater than $10,000. Five reported fires exceeded $10,000 and are considered anomalies subject to individual analysis. These five fires have been segregated from the sample considered in this study to avoid biasing the cost data of the remaining 181 fire incidents.

Table 1 also indicates that the major causes of fire in USN aircraft hangars are electrical (53.2 percent), careless disposal of smoking material (9.7 percent),

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[1]False alarms are the actuation of an automatic detection/suppression system with no associated fire.

[2]All tables appear in Appendix C.

incendiarism[3] (8.1 percent), and flammable liquids and gases (8.1 percent).

In this chapter, an analysis is made of the major cause of fire--electrical fires--and other information from the data base to demonstrate the value of a computerized data base as a management tool.

Electrical Fires

The data base categorized the electrical causes of fire into three subgroups: electrical devices, electrical conveyors, and fluorescent lights. Electrical conveyors include wiring, cables, fuses, and transformers (14).

Number of Electrical Fires

Table 1 indicates that 99 (53.2 percent) of the 186 fires were due to electrical causes. Of these, electrical devices accounted for thirty-six, electrical conveyors for twenty-eight, and fluorescent lights for thirty-five.

Table 2 addresses the contributing causes of the electrical fires: eighty-one (81.8 percent) were caused by defective equipment, seven (7.1 percent) by improper maintenance, and six (6.1 percent) by improper operating procedures. The Director of Fire Protection, USAF, has stated that these contributing causes of fire in buildings

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[3] Incendiarism is defined in the data base as arson (14).

are of great concern to the USAF (8). A computerized data base could be used to assist management in the selection of installed equipment, in the revision of maintenance standards, and in the establishment of operating standards.

Table 3 indicates that electrical fire incidents in USN aircraft hangars have been increasing yearly for the past four years. This increase could be attributed to a number of factors including, inter alia, the upgrading of hangar lighting by installing fluorescent lights, an increased number of hangars, and the need for replacement of electrical wiring. A data base could identify such factors and thereby enable management to consider any necessary corrective action.

Dollar Loss due to Electrical Fires

Table 1 indicates that the total dollar loss for all fires with an individual fire loss less than $10,000 was $68,020. Electrical fires caused $32,814 (48.2 percent) of this dollar loss. In particular, electrical conveyor fires caused $23,872 (72.7 percent) of the total loss due to electrical causes. Fifty-eight percent ($19,090) of the total dollar loss due to electrical fires was caused by six conveyor fires. The high cost for a few electrical conveyor fires could be explained by the possibility of such fires remaining undetected for a longer period due to the concealment of wiring behind building construction

materials. This situation raises the question of desirable detection methods for electrical fires.

Method of Detection

Fires in USN hangars can be detected automatically either by operation of an installed sprinkler system or an installed detection system. Table 4 indicates that ninety (90.9 percent)[4] of the electrical fires occurred in hangars equipped with an automatic sprinkler system. Table 5 indicates that two of the electrical fires occurred in hangars equipped with an automatic detection system.

Table 6 indicates that eighty-nine (89.9 percent) of the electrical fires were detected by occupants of the hangar and only three fires by automatic devices. The data base does not identify whether the hangars were occupied or unoccupied when automatic detection occurred. The size of the data sample does not permit the conclusion to be drawn that automatic sprinkler detection/suppression systems result in a lower dollar loss for electrical fires.

In the USAF, where early warning detection systems, rate of temperature rise detection systems, and automatic sprinkler systems are installed, significant trends identifying desirable detection systems could possibly be identified using a data base of historical fire incidents.

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[4]The ninety electrical fires exclude the missing cases and the fires in buildings not equipped with sprinklers.

Method of Extinguishment

Table 7 indicates that twenty-six (26.3 percent) of all electrical fires were extinguished by the occupants of the hangars prior to the arrival of the fire department. Table 7 also indicates that sixty-five (65.6 percent) of all electrical fires were put out by turning off the electrical power; 12.1 percent by the occupants prior to the arrival of the fire department and 53.5 percent by the fire department. The data base does not indicate whether occupants are permitted to turn off the electrical power when fire incidents occur. The data base could be used to identify a need for the training of occupants in the early fire safety reactions required prior to the arrival of the fire department.

Additional Information from a Data Base

The previous section focused on one specific data element--the electrical causes of fire--in the USN data base. This section briefly discusses some additional information which could be ascertained, inter alia, from a computerized data base.

False Alarms

The USN data base contains 358 (66 percent) false alarm incidents. Table 8 identifies the frequency of false alarms from each type of installed sprinkler system.

Deluge system false alarms account for 286 (79.8 percent) of all false alarms reported. Although this statistic may appear significant, the actual significance can only be determined if the total number of sprinkler systems by type in all USN aircraft hangars is known. This information was not available for this study. The Director of Fire Protection, USAF, has stated that false alarm incidence is a problem area in the USAF in terms of both resultant damage/maintenance costs and also fire department manning committment (8). The USAF has a data base which details the real property in all USAF facilities: HAF-PRE(AR)7115, *USAF Real Property Inventory Detail Report* (15). This data base could be accessed to determine the number of sprinkler systems by type installed in all USAF facilities.

In many cases, the recurrence of false alarms could be reduced by better selection of fire detection/suppression equipment and also by management identifying areas of need for improved maintenance. A data base could be an effective tool for identifying such problem areas, thereby, enabling management to initiate corrective action. Table 2, for example, indicates that 117 (32.7 percent) of all false alarms were caused by defective equipment.

Sprinkler Status

Table 9 depicts the frequency of fires in dollar loss intervals for varying degrees of sprinkler operation. The following information from this crosstabulation is of interest:

1. Five fires incurred a dollar loss exceeding $10,000 for each fire. Of these five fires, three fires occurred in aircraft hangars which were not sprinkler protected.

2. Forty fires were in hangars equipped with deluge system protection. In two cases the deluge system operated, but in one of these cases the system did not control the fire. In the remaining thirty-eight cases the fires were extinguished before the system operated.

3. One hundred nineteen (119) fires were in hangars equipped with wet pipe sprinkler protection. In sixteen cases the system controlled the fire, and in seven cases extinguished the fire. In the remaining ninety-six cases the fires were extinguished before the wet pipe system operated.

4. One fire occurred in a hangar equipped with a dry pipe sprinkler system. In this case, the system extinguished the fire.

Although no significant conclusion can be drawn as to the effectiveness of the three sprinkler system types

without further analysis, it is noted that the potential loss in nonsprinklered hangars could be significant. As mentioned previously, false alarm incidence for each sprinkler system type is also an important variable to consider in determining the most desirable sprinkler system to select.

Fire Department Role

The fire department responds to all fire incidents; both fires and false alarms (4). Table 7 indicates that the fire department extinguished 117 fires (63.0 percent of all fires). The response time of the fire department could be an important variable, particularly in terms of reduction of total dollar loss per fire incident: the assumption being that the longer the fire remains unattended the greater the loss. The USN data base does not address response time. The authors recommend that this variable be included in a USAF data base.

The time period in which fires occur could be another important variable, particularly in relation to determining the manning levels of the fire department. The USN data base addresses the time period variable by both hour of the day and day of the month. Table 10 and the histogram in Figure 1 depict the frequency of fire alarms and fire incidents for time intervals during the day for all days during the ten-year reporting period. The fire incidents/alarms peak during the 1200 to 1500

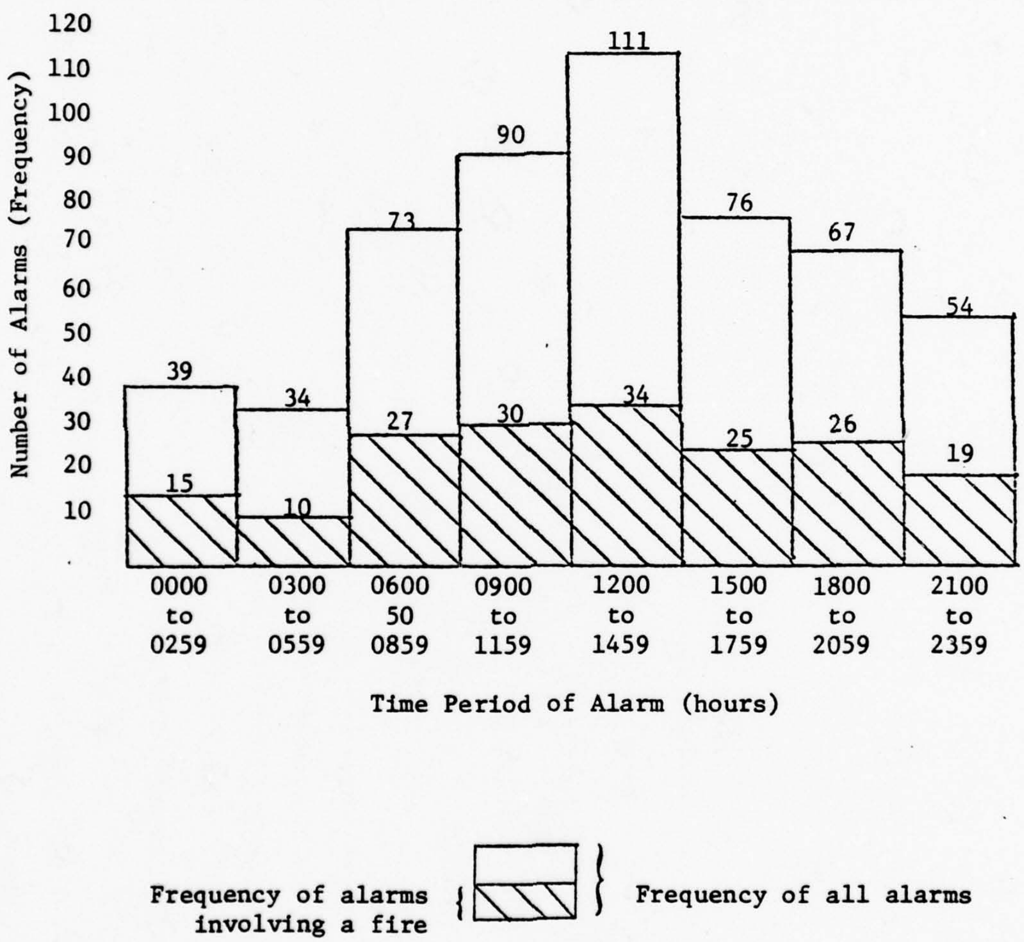

Fig. 1. Histogram of Frequency of All Fire Alarms and All Fire Alarms Involving Fires

hours time interval, with the minimum number occurring during the 0000 to 0300 hours period. Hangar fire alarm incidents do not provide an adequate base to justify manning committments of the fire department. However, a data base which addresses fire incidents/alarms in all facilities could provide important information for justifying or establishing fire department manning requirements.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this study has been to demonstrate the value of a computerized data base of fire incidents to USAF management. The conclusions drawn relate to USN data and therefore may not be indicative of situations in the USAF. The study identified the following findings:

1. During the period 1 January 1968 to 31 December 1977, 544 fire incidents--358 false alarms and 186 fires--in USN hangars were reported.

2. Five fires each exceeded $10,000 loss.

3. Of all fires, 63.0 percent were extinguished by the fire department.

4. Of all hangars involved in fire, 90 percent (168) were equipped with an automatic detection/suppression systems.

5. Of all fires, 92.0 percent were detected by other than automatic detection/suppression systems.

6. Fires due to electrical causes accounted for 53.2 percent of all fires and also for 48.2 percent of the dollar loss for all individual fires under $10,000.

7. Of all electrical fires, 81.8 percent were caused by defective equipment.

8. Of all fires, 46.2 percent were caused by defective equipment.

9. The number of electrically caused fires in USN hangars have been increasing annually for the last four years.

10. Of all electrical fires, 65.6 percent were put out by turning off the electrical power.

11. False alarms in deluge sprinkler systems accounted for 79.8 percent of all reported false alarms.

This study also highlighted some specific types of information which a readily accessible data base could provide, including:

1. Identification of the major causes of fire and factors contributing to those causes.

2. Identification of the most effective fire detection/suppression systems, particularly in relation to false alarm incidence rates.

3. Identification of any need to revise maintenance standards, operating standards, and personnel training requirements.

4. Identification of the fire incident frequency by time period to assist management in determining manning requirements for the fire department.

5. Identification of the causes, costs, and frequency of false alarms.

The information available from a data base is by no means restricted to the above. The list of variables available in the USN data base is detailed in Appendix B.

Potential fire loss is an indeterminate quantity being directly dependent on a number of factors including the type of weapon system or aircraft which may be in a hangar. For example, Appendix A states that a major assumption of the USAF policy for fire protection in aircraft hangars is the high potential loss from an ignited fuel spill. This assumption cannot be confirmed or denied from the USN data base. A data base is not a panacea of information for instant decisions. It is a management tool; an aid to, and not a substitute for, specific knowledge and managerial ability.

Recommendations

A computerized data base for fire incidents has not been compiled in the USAF (8). This study has established that such a data base could be an effective management tool for assessing fire loss and also for justifying existing or proposed fire protection policy.

The authors recommend that a computerized data base of fire incidents be compiled in the USAF and also that the following factors be considered:

1. The data base should include fire incidents/ alarms which occur in all USAF facilities.

2. The data base should be capable of integration with the existing USAF data base addressing real property assets: HAF-PRE (AR) 7115, *USAF Real Property Inventory Detail Report.*

3. The variables addressed by the USN data base, detailed in Appendix A, should be adapted to a USAF data base as applicable.

4. The following additional variables should be considered for inclusion in the data base:

a. *"Fire department response time"* for use in determining whether a relationship exists between dollar loss and fire department response time.

b. *"Time the fire incident was terminated"* for use in forecasting the time committment of the fire department at fire incidents.

c. *"Operational status of the facility"* for use in identifying if the facility was occupied/unoccupied at the time of the fire incident.

APPENDIXES

APPENDIX A

ASSUMPTIONS

The assumptions upon which the USAF policy for fire protection in aircraft hangars is based are (15):

1. Normally, combustible material inside a hangar will be Class "B"; i.e., jet fuel, hydraulic fluid and purge fluid. Because such hazards usually directly involve an aircraft, there can be very serious damage in a very short time with the high heat release from flammable liquids.

2. A minor fuel leak on a ramp is much less serious than a fuel leak within a hangar where vapors can accumulate.

3. The USAF uses oscillating monitors for low level fire protection. These monitors in real-work situations may be blocked or otherwise partially obstructed by test stands and other maintenance equipment.

4. Hangars vary in size and usage and in the value of aircraft to be housed. However, in all cases, it must be appreciated that an aircraft being serviced may be immobilized and cannot be moved in the event of fire.

5. The greatest threat within a hangar is that of the large fuel spill, which, if ignited, will rapidly create thermal exposure to an aircraft and the hangar structure.

6. The critical danger to an aircraft is a fire directly below or within the fuselage and/or wings.

7. Contiguous shops, and the work carried out therein, impose a hazard on a hangar. If these shops are not suitably separated or isolated they will provide a ready means for fire to penetrate into the hangar.

8. Each and every type of hangar and/or aircraft deserves individual consideration and no standard can be produced which adequately covers all aspects and eventualities. Assessment and selection of the fire protection measures for specific hangars is necessary.

APPENDIX B

NOMINAL VARIABLES IN USN DATA BASE

The following is a listing of the nominal variables available in the USN computerized data base (only those variables directly applicable to fires/alarms in aircraft hangars will be considered in this study)(14):

Type of Alarm

1. Fire involving:

    a. Buildings (including tents)

    b. Aircraft (other than crash)

    c. Automotive vehicles and equipment

    d. Housing trailers

2. Operation of fixed extinguishing systems, with no related fire

Hangar Occupancy

1. Activities under the control of the Department of the Navy

2. Facilities under construction at Naval installations including government-furnished materials

3. Navy-owned buildings, supplies, materials, machine tools and production equipment in privately-owned or managed plants

Major Factors Contributing to Spread of Fire

1. Poor housekeeping

2. Combustible interior wall and ceiling finish

3. Lack of proper vertical fire cutoffs

4. Lack of proper horizontal fire cutoffs

5. Combustible elements of construction

6. Presence of concealed spaces

7. Hazardous operations and/or storage of hazardous materials

8. Failure of built-in extinguishing systems

9. Delayed discovery and/or alarm

10. Not classified above

Sprinkler Status

1. No operation or sprinkler system:

    a. Building not equipped with sprinklers

    b. Wet pipe system provided but not in service

    c. Dry pipe system provided but not in service

    d. Deluge system provided but not in service

    e. Operation of sprinklers not applicable

2. Wet pipe system operated for reasons other than fire:

    a. Unusual heat source

    b. Mechanical damage (including freeze-ups)

    c. Defective equipment or improper installation

    d. Lack of proper maintenance

3. Dry pipe system operated for reasons other than fire:

    a. Unusual heat source

    b. Mechanical damage (including freeze-ups)

    c. Defective equipment or improper installation

    d. Lack of proper maintenance

4. Deluge system operated for reasons other than fire:

    a. Unusual heat source

    b. Mechanical damage

c. Defective equipment or improper installation

d. Lack of proper maintenance

e. Operated manually

5. Wet Pipe System

   a. Fire extinguished prior to sprinkler operation

   b. Sprinklers extinguished fire

   c. Sprinklers did not extinguish, but controlled fire

   d. Sprinklers did not control fire due to:

      (1) Partial coverage

      (2) Inadequate water supply

      (3) Closed valve

      (4) Obstructions to sprinkler heads or in pipings and lines

      (5) Occupancy hazard too severe for protection installed

      (6) Frozen mains or lines

      (7) Reasons other than above

6. Dry Pipe System

   a. Fire extinguished prior to sprinkler operation

   b. Sprinklers extinguished fire

   c. Sprinklers did not extinguish, but controlled fire

   d. Sprinklers did not control fire due to:

      (1) Partial coverage

      (2) Inadequate water supply

      (3) Closed valve

      (4) Obstructions to sprinkler heads, or in piping and lines

(5) Occupancy hazards too severe for protection installed

(6) Frozen mains or lines

(7) Reasons other than above

7. Deluge of Water Spray Systems

a. Fire extinguished prior to sprinkler operation

b. Sprinklers extinguished fire

c. Sprinklers did not extinguish, but controlled fire

d. Sprinklers did not control fire due to:

(1) Partial coverage

(2) Inadequate water supply

(3) Closed valve

(4) Obstructions to sprinkler heads, or in piping and lines

(5) Occupancy hazard too severe for protection installed

(6) Inadequacy of design

(7) Reasons other than above

8. Not classified above

<u>Automatic Fire Alarm Systems</u>

1. Automatic fire alarm system not provided

2. Fixed temperature system provided:

a. Not in service

b. Fire extinguished prior to system operation

c. Operated automatically satisfactorily

d. Operated manually satisfactorily

e. Did not operate

f. Operated unsatisfactorily

g. Operation not applicable

h. Operated for reasons other than fire

3. Rate of rise system provided:

a. Not in service

b. Fire extinguished prior to system operation

c. Operated automatically satisfactorily

d. Operated manually satisfactorily

e. Did not operate

f. Operated unsatisfactorily

g. Operation not applicable

h. Operated for reasons other than fire

4. Combination fixed temperature and rate of rise system provided:

a. Not in service

b. Fire extinguished prior to system operation

c. Operated automatically satisfactorily

d. Operated manually satisfactorily

e. Did not operate

f. Operated unsatisfactorily

g. Operation not applicable

h. Operated for reasons other than fire

5. Smoke detection system provided:

a. Not in service

b. Fire extinguished prior to operation of system

c. Operated automatically satisfactorily

d. Operated manually satisfactorily

e. Did not operate

f. Operated unsatisfactorily

g. Operation not applicable

h. Operated for reasons other than fire

6. Ionization type system provided:

   a. Not in service

   b. Fire extinguished prior to operation of system

   c. Operated automatically satisfactorily

   d. Operated manually satisfactorily

   e. Did not operate

   f. Operated unsatisfactorily

   g. Operation not applicable

   h. Operated for reasons other than fire

7. Not classified above

Manual Fire Alarm Systems

1. Building not provided with manual alarm system

2. Manual alarm system with connection to fire alarm headquarters:

   a. Not in service

   b. Operation not applicable

   c. Was not operated

   d. Operated satisfactorily

   e. Operated unsatisfactorily

   f. Operated for reasons other than fire

3. Manual alarm system not provided with connection to fire headquarters:

    a. Not in service

    b. Operation not applicable

    c. Was not operated

    d. Operated satisfactorily

    e. Operated unsatisfactorily

    f. Operated for reasons other than fire

4. Not classified above

Portable Fire Extinguishers

1. Extinguishers not provided

2. Operation not applicable

3. Were not used

4. Operated satisfactorily

5. Operated unsatisfactorily

Method of Detection

1. Not applicable

2. Detected by:

    a. Occupants

    b. Watchman

    c. Roving patrols

    d. Passerby

    e. Others

3. Sprinkler or other automatic extinguishing system

4. Fire detecting system

5. Other means

Method of Alarm Transmittal

1. Not transmitted at time of fire
2. Verbally or visually
3. Fire alarm box:
   a. Operated manually
   b. Connected to sprinkler or other automatic extinguishing system
   c. Connection to automatic fire alarm system
   d. Connection to manual fire alarm system
4. Fire reporting telephone system
5. Standard telephone
6. Radio
7. Other

Cause of Fire

1. Not applicable
2. Aircraft of vehicle crash
3. Ashes--embers
4. Careless disposal of smoking material
5. Chimneys, flues, smokepipes, stacks (defective installation or failure)
6. Combustibles near heaters or other heat sources (light bulbs, etc.)
7. Electricity:
   a. Devices using electrical power, including attached cords
   b. Conveyors of electricity, wiring, cables, fuses, switches, transformers, etc.
   c. Fluorescent lights, ballasts, starters, etc.

8. Explosion resulting in fire

9. Friction

10. Incendiarism

11. Industrial heat producing equipment (drying ovens, heat-treating furnaces, etc.)

12. Internal combustion equipment

13. Lightning resulting in fire

14. Matches and lighters

15. Misuse, operational or mechanical failure involving flammable liquids or gases

16. Exposure--accidental

17. Exposure--intentional (uncontrolled burning)

18. Overheated tar, wax

19. Sparks and flying brands

20. Spontaneous ignition

21. Steampipes, airducts, heat or exhaust conveyors

22. Static sparks

23. Furnaces, heaters (building heat, hot water, etc.)

24. Cooking: ranges, ovens, overheated grease and cooking oils

25. Deep fat fryers

26. Welding and open flame equipment

27. Undetermined

28. Known, but not classified above

<u>Outside Aid</u>

1. Not called

2. Called but not used

3. Called and used

4. Responded to call for aid from off station (mutual aid)

<u>Method of Control</u>

1. Not applicable

2. Not extinguished, allowed to burn out

3. Extinguished prior to arrival of fire department by:

    a. Hand, portable fire equipment

    b. Direct hydrants or standpipe hose lines

    c. De-energized electrical power

    d. Other means

    e. Garden hose

4. Extinguished by fire department by:

    a. Hand, portable fire equipment

    b. Preconnected booster or hand hose lines from pumpers

    c. Direct hydrant or standpipe hose lines

    d. Hose lines from pumpers taking suction from hydrants or surface water

    e. De-energized electrical power

    f. Other means

5. Extinguished by automatic sprinklers or other built-in extinguishing systems

6. Extinguished by occupants after control by automatic sprinkler or other built-in extinguishing systems by:

    a. Hand, portable fire equipment

    b. Direct hydrants or standpipe hose lines

    c. Other means

7. Extinguished by fire department after control by automatic sprinklers or other built-in extinguishing system by:

    a. Hand, protable fire equipment

    b. Preconnected booster or hand hose lines from pumpers

    c. Direct hydrant or standpipe hose lines

    d. Hose lines from pumpers taking suction from hydrants or surface water

    e. Other means

8. Not covered above

<u>Type of Construction and Interior Finish</u>

1. Not applicable

2. Wood frame:

    a. No interior finish

    b. Combustible interior finish:

        (1) Plywood

        (2) Low density fiberboard

        (3) High density fiberboard

        (4) Acoustical tile or insulation

        (5) Other

    c. Noncombustible interior finish:

        (1) Plaster

        (2) Gypsum board

        (3) Other

3. Wood frame with sheet metal or asbestos siding and roofing:

    a. No interior finish

b. Combustible interior finish:

(1) Plywood

(2) Low density fiberboard

(3) High density fiberboard

(4) Acoustical tile or insulation

(5) Other

c. Noncombustible interior finish:

(1) Plaster

(2) Gypsum board

(3) Other

4. Masonry walls, wood floors and roof:

a. No interior finish

b. Combustible interior finish:

(1) Plywood

(2) Low density fiberboard

(3) High density fiberboard

(4) Acoustical tile or insulation

(5) Other

c. Noncombustible/interior finish:

(1) Plaster

(2) Gypsum board

(3) Other

5. Steel frame with sheet metal or asbestos siding and roofing:

a. No interior finish

b. Combustible interior finish:

(1) Plywood

(2) Low density fiberboard

(3) High density fiberboard

(4) Acoustical tile or insulation

(5) Other

c. Noncombustible interior finish:

(1) Plaster

(2) Gypsum board

(3) Other

6. Steel frame, masonry walls

a. No interior finish

b. Combustible interior finish:

(1) Plywood

(2) Low density fiberboard

(3) High density fiberboard

(4) Acoustical tile or insulation

(5) Other

c. Noncombustible interior finish:

(1) Plaster

(2) Gypsum board

(3) Other

7. Fire Restrictive

a. No interior finish

b. Combustible interior finish:

(1) Plywood

(2) Low density fiberboard

(3) High density fiberboard

(4) Acoustical tile or insulation

(5) Other

c. Noncombustible interior finish:

(1) Plaster

(2) Gypsum board

(3) Other

8. Not covered above

<u>Major Cause of Fire</u>

1. Not applicable
2. Improper maintenance
3. Improper operating procedures
4. Improper or defective equipment
5. Improper installation of equipment
6. Poor housekeeping
7. Human element failure
8. Not classified above

APPENDIX C

ANALYSIS TABLES

TABLE 1

CROSS TABULATION OF CAUSES OF FIRE WITH LOSS GROUP BY FREQUENCY AND TOTAL DOLLAR LOSS
(From a Census of Fire Alarm Occurrences in USN Hangars:
January 1968 to 31 December 1977)

Causes of Fire	Loss Group Frequency		Total Frequency	Percent of Total	Loss Group ($)	
	<$10,000	≥$10,000			<$10,000	≥$10,000
Aircraft/Vehicle Crash	0	1	1	.5		11,673,225
Smoking Material	17	1	18	9.7	1,169	15,668
Combustibles Near Heat	3	0	3	1.6	1,080	
*Electric Devices**	36	0	36	19.3	8,061	
*Electric Conveyors**	28	0	28	15.1	23,872	
*Fluorescent Lights**	35	0	35	18.8	881	
Friction	1	0	1	.5	25	
Incendiarism	14	1	15	8.1	2,560	25,600
Ovens/Furnaces	2	0	2	1.1	3,400	
I.C. Equipment	2	0	2	1.1	562	
Matches/Lighters	1	0	1	.5	350	
Flamm. Liquids/Gases	15	0	15	8.1	1,610	
Overheated Tar/Wax	2	0	2	1.1	40	
Spontan. Ignition	2	0	2	1.1	965	
Static Sparks	3	1	4	2.2	20	17,473
Bldg. Heating Equipment	1	0	1	.5	657	
Deep Fat Fryers	1	0	1	.5	275	
Welding Equipment	9	0	9	4.8	13,941	
Undetermined	7	1	8	4.3	1,747	250,000
Known, not classified	2	0	2	1.1	6,805	
Total	181	5	186	100.0	68,020	12,049,986

*Electrically caused fires are significantly more frequent.

TABLE 2

CROSS TABULATION OF MAJOR FACTORS CONTRIBUTING TO CAUSES OF FIRE WITH ELECTRICAL FIRES, ALL FIRES, AND FALSE ALARMS BY FREQUENCY AND PERCENTAGE OF OCCURRENCE
(From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Factor	Electrical Fires Only		All Fires (Including Electrical)		False Alarms		Total (All Fires and False Alarms)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Improper Maint.	7	7.1	10	5.4	12	3.3	22	4.0
Improper Operating Procedure	6	6.1	25	13.4	31	8.6	56	10.3
Defective Equip.	81	81.8	86	46.2	117	32.7	203	37.4
Improperly Installed Equip.	2	2.0	2	1.1	2	0.6	4	0.7
Poor Housekeeping	0	0.0	2	1.1	0	0.0	2	0.4
Human Element	1	1.0	47	25.3	97	27.1	144	26.5
Factor Not Classified	1	1.0	2	1.1	2	0.6	4	0.7
Data Missing	1	1.0	12	6.4	97	27.1	109	20.0
Total	99	100.0	186	100.0	358	100.0	544	100.0

TABLE 3

CROSS TABULATION OF YEAR WITH ELECTRICAL FIRES AND ALL FIRES BY FREQUENCY AND PERCENTAGE OF OCCURRENCE (From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

	Electrical Fires		All Fires (Including Electrical)	
Year	Frequency	Percent	Frequency	Percent
1968	13	13.1	24	12.9
1969	3	3.0	16	8.6
1970	4	4.0	9	4.8
1971	5	5.1	11	5.9
1972	6	6.1	13	7.0
1973	2	2.0	6	3.2
1974	9	9.1	17	9.1
1975	12	12.1	23	12.4
1976	20	20.2	31	16.7
1977	25	25.3	36	19.4
Total	99	100.0	186	100.0

TABLE 4

CROSS TABULATION OF AUTOMATIC SPRINKLER STATUS WITH ELECTRICAL FIRES AND ALL FIRES BY FREQUENCY AND PERCENTAGE OF OCCURRENCE
(From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Sprinkler Status	Electrical Fires		All Fires	
	Frequency	Percent	Frequency	Percent
Building Not Equipped With Sprinklers	4	4.0	18	9.7
Fire Extinguished Prior To Wet Pipe System Operation	66	66.7	96	51.6
Wet Pipe System Extinguished Fire	2	2.0	7	3.8
Wet Pipe System Controlled Fire	3	3.0	16	8.6
Dry Pipe System Extinguished Fire	0	0.0	1	.6
Fire Extinguished Prior To Deluge System Operation	19	19.2	38	20.4
Deluge System Controlled Fire	0	0.0	1	.5
Deluge System Did Not Control Fire	0	0.0	1	.5
Data Missing From Case	5	5.1	8	4.3
Total	99	100.0	186	100.0

TABLE 5

CROSS TABULATION OF TYPE OF AUTOMATIC ALARM SYSTEM WITH ELECTRICAL FIRES, ALL FIRES, AND FALSE ALARMS BY FREQUENCY OF OCCURRENCE (From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Type of Automatic Alarm	Electrical Fires	All Fires Including Electrical	All Fire Alarms
Not Provided	97	179	534
Fixed Temperature System	...	3	3
Rate of Rise System (ROR)	1	2	4
Combined Fixed Temp/ROR System	1	1	1
Smoke Detection System	...	1	1
Total	99	186	544

TABLE 6

CROSS TABULATION OF METHOD OF DETECTION WITH ELECTRICAL FIRES AND ALL FIRES BY FREQUENCY AND PERCENTAGE OF OCCURRENCE
(From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Method of Detection	Electrical Fires		All Fires (Including Electrical)	
	Frequency	Percent	Frequency	Percent
Occupants	89	89.9	147	79.0
Watchman	4	4.1	11	5.9
Roving Patrols	0	0.0	5	2.7
Passerby	0	0.0	4	2.2
Others	3	3.0	4	2.2
Automatic Extinguishing System*	3	3.0	15	8.0
Total	99	100.0	186	100.0

*Automatic extinguishing systems also detect fires.

TABLE 7

CROSS TABULATION OF HOW FIRE WAS EXTINGUISHED WITH ELECTRICAL FIRES AND ALL FIRES BY FREQUENCY AND PERCENTAGE OF OCCURRENCE
(From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

How Fire Was Extinguished	Electrical Fires		All Fires (Including Electrical)	
	Frequency	Percent	Frequency	Percent
Allowed to Burn Out	3	3.0	8	4.3
Occupants Using Portable Fire Equipment	13*	13.2	35	18.8
Occupants by De-Energising Electrical Power	12*	12.1	14	7.5
Occupants Using Other Means	1*	1.0	6	3.2
Fire Department Using Portable Fire Equipment/Pumpers	12	12.1	47	25.3
Fire Department by De-Energising Electrical Power	53	53.5	54	29.1
Automatic Sprinklers	1	1.0	6	3.2
Automatic Sprinklers and Fire Department	4	4.1	16	8.6
Total	99	100.0	186	100.0

*Twenty-six electrical fires were extinguished by the occupants prior to the arrival of the fire department.

TABLE 8

CROSS TABULATION OF AUTOMATIC SPRINKLER STATUS WITH FALSE ALARMS BY FREQUENCY AND PERCENTAGE (From a Census of Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Sprinkler Status	False Alarms		False Alarms per System	
	Frequency	Percent	Frequency	Percent
Not Sprinkler Equipped	1	0.3	1	0.3
Wet Pipe System			64	17.8
Unusual Heat	25	7.0		
Mechanical Damage	32	8.8		
Defective Equipment	7	2.0		
Dry Pipe System			2	0.6
Unusual Heat	1	0.3		
Mechanical Damage	1	0.3		
Deluge System			286	79.8
Unusual Heat	78	21.7		
Mechanical Damage	20	5.6		
Defective Equipment	108	30.2		
No Proper Maintenance	20	5.6		
Operated Manually	60	16.8		
Unknown Response	1	0.3	1	0.3
Not Classified	1	0.3	1	0.3
Missing Cases	3	0.8	3	0.8
Total	358	100.0	358	100.0

TABLE 9

CROSS TABULATION OF AUTOMATIC SPRINKLER STATUS WITH INDIVIDUAL FIRE LOSS GROUPED AS LESS THAN AND GREATER THAN OR EQUAL TO $10,000 BY FREQUENCY OF OCCURRENCE
(From a Census of USN Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 December 1977)

Sprinkler Status	Number of Fires		
	<$10,000	≥$10,000	Total
Building Not Equipped with Sprinklers	15	3	18
Fire Extinguished Prior to Wet Fire System Operation	96	0	96
Wet Pipe System Extinguished Fire	6	1	7
Wet Pipe System Controlled Fire	16	0	16
Dry Pipe System Extinguished Fire	1	0	1
Fire Extinguished Prior to Deluge System Operation	38	0	38
Deluge System Controlled Fire	1	0	1
Deluge System Did Not Control Fire	0	1	1
Data Missing from Case	8	0	8
Total	181	5	186

TABLE 10

CROSS TABULATION OF DAILY TIME PERIOD WITH ALL FIRES AND ALL FIRE ALARMS (INCLUDING ALL FIRES) BY FREQUENCY AND PERCENTAGE OF OCCURRENCE (From a Census of USN Fire Alarm Occurrences in USN Hangars: 1 January 1968 to 31 Decmeber 1977)

Time Period of Day (Hours)	Fire Incidents		Fire Alarms (Including Fire Incidents)	
	Frequency	Percent	Frequency	Percent
0000 to 0259	15	8.1	39	7.2
0300 to 0559	10	5.4	34	6.3
0600 to 0859	27	14.5	73	13.4
0900 to 1159	30	16.1	90	16.5
1200 to 1459	34	18.3	111	20.4
1500 to 1759	25	13.4	76	14.0
1800 to 2059	26	14.0	67	12.3
2100 to 2359	19	10.2	54	9.9
Total	186	100.0	544	100.0

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